

CLAIMS

What is claimed is:

1. A control circuit for controlling a motor, the control circuit comprising:
a contactor circuit including a contactor and having first and second ends; and
5 a snubber circuit connected across the contactor circuit, the snubber circuit including
a first port electrically connected to the first end of the contactor
circuit,
a second port electrically connected to the second end of the contactor
10 circuit,
a first sub-circuit electrically connected to one of the first and second
ports, the first sub-circuit including a resistor and a non-linear device electrically
connected in parallel branches, and
a second sub-circuit electrically connected in series with the first sub-
15 circuit and to the other of the first and second ports, the second sub-circuit including
an energy storage device.
2. A control circuit as set forth in claim 1 wherein the non-linear device includes
a diode.
- 20 3. A control circuit as set forth in claim 1 wherein the energy storage device
includes a capacitor.
4. A control circuit as set forth in claim 1 wherein the snubber circuit receives a
25 first current flowing from the first port through the first and second sub-circuits to the
second port, and wherein a substantial portion of the first current flows through the
non-linear device when the first current flows through the first sub-circuit.
5. A control circuit as set forth in claim 4 wherein the energy storage device
30 charges when the first current flows through the second sub-circuit.

6. A control circuit as set forth in claim 5 wherein the energy storage device discharges when the contactor is closed, wherein the energy discharged from the energy storage device creates a second current that flows through the first sub-circuit opposite the first current, and wherein a substantial portion of the second current
5 flows through the resistor when the second current flows through the first sub-circuit.

7. A control circuit as set forth in claim 1 wherein the non-linear device is a first diode, wherein the second sub-circuit further includes a second non-linear device, and wherein the energy storage device and the second non-linear device are electrically
10 connected in parallel branches.

8. A control circuit as set forth in claim 7 wherein the first and second non-linear devices each includes a diode, and wherein the energy storage device includes a capacitor.
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9. A control circuit as set forth in claim 7 wherein the snubber circuit receives a first current flowing from the first port through the first and second sub-circuits to the second port, and wherein a substantial portion of the first current flows through the first non-linear device when the first current flows through the first sub-circuit.
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10. A control circuit as set forth in claim 9 wherein the energy storage device charges when the first current flows through the second sub-circuit.

11. A control circuit as set forth in claim 10 wherein the energy storage device discharges when the contactor is closed, wherein the energy discharged from the energy storage device creates a second current that flows through the first sub-circuit opposite the first current, and wherein the a substantial portion of the second current
25 flows through the resistor when the second current flows through the first sub-circuit.

12. A control circuit as set forth in claim 9 wherein the snubber circuit receives a second current flowing from the second port through the first and second sub-circuits to the first port, and wherein a substantial portion of the second current flows through the second non-linear device when the second current flows through the second sub-circuit.

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13. A control circuit for controlling a motor, the control circuit comprising:
a contactor circuit including a contactor and having first and second ends; and
a snubber circuit connected across the contactor circuit, the snubber circuit
including

5 a first port electrically connected to the first end of the contactor
circuit;

a second port electrically connected to the second end of the contactor
circuit;

10 a first sub-circuit electrically connected to one of the first and second
ports, the first sub-circuit including a resistor and a first non-linear device electrically
connected in parallel branches; and

15 a second sub-circuit electrically connected in series with the first sub-
circuit and to the other of the first and second ports, the second sub-circuit including a
energy storage device and a second non-linear device electrically connected in
parallel branches.

14. A control circuit as set forth in claim 13 wherein the snubber circuit receives a
first current flowing from the first port through the first and second sub-circuits to the
second port, wherein a substantial portion of the first current flows through the non-
20 linear device when the first current flows through the first sub-circuit, and wherein the
energy storage device charges when the first current flows through the second sub-
circuit.

15. A control circuit as set forth in claim 14 wherein the energy storage device
25 discharges when the contactor is closed, wherein the energy discharged from the
energy storage device creates a second current that flows through the first sub-circuit
opposite the first current, and wherein a substantial portion of the second current
flows through the resistor when the second current flows through the first sub-circuit.

30 16. A control circuit as set forth in claim 15 wherein the first and second non-
linear devices each includes a diode, and where the energy storage device includes a
capacitor.

17. A control circuit for controlling a motor, the control circuit comprising:
a contactor circuit including a contactor and having first and second ends; and
a snubber circuit connected across the contactor circuit, the snubber circuit
including

5 a first port electrically connected to the first end of the contactor circuit
and operable to receive a first current flow having a first direction,

a second port electrically connected to the second end of the contactor
circuit and operable to receive a second current flow having a second direction
opposite the first direction,

10 a first sub-circuit electrically connected to one of the first and second
ports and including a resistor and a first diode electrically connected in circuit in
parallel branches, the first diode being operable to allow a substantial portion of the
first current to flow through the first diode when the first current flows through the
first sub-circuit, and the resistor being operable to allow a substantial portion of the
15 second current to flow through the resistor when the second current flows through the
first sub-circuit, and

a second sub-circuit electrically connected in series with the first sub-
circuit and to the other of the first and second ports, the second sub-circuit including a
capacitor and a second diode electrically connected in circuit in parallel branches, the
20 second diode being operable to allow a substantial portion of the second current to
flow through the second diode when the second current flows through the first sub-
circuit, and the capacitor charges when the first current flows through the second sub-
circuit.

18. A vehicle comprising:

a motor; and

a control circuit operable to control the motor, the control circuit including a
contactor circuit having a contactor, a first end and a second end, and a snubber
5 circuit connected across the contactor circuit, the snubber circuit including

a first port electrically connected to the first end of the contactor
circuit,

a second port electrically connected to the second end of the contactor
circuit,

10 a first sub-circuit electrically connected to one of the first and second
ports, the first sub-circuit including a resistor and a non-linear device electrically
connected in parallel branches, and

a second sub-circuit electrically connected in series with the first sub-
circuit and to the other of the first and second ports, the second sub-circuit including
15 an energy storage device.

19. A vehicle as set forth in claim 18 wherein the non-linear device includes a
diode.

20. A vehicle as set forth in claim 18 wherein the energy storage device includes a
capacitor.

21. A vehicle as set forth in claim 18 wherein the snubber circuit receives a first
current flowing from the first port through the first and second sub-circuits to the
25 second port, and wherein a substantial portion of the first current flows through the
non-linear device when the first current flows through the first sub-circuit.

22. A vehicle as set forth in claim 21 wherein the energy storage device charges
when the first current flows through the second sub-circuit.

23. A vehicle as set forth in claim 22 wherein the energy storage device
discharges when the contactor is closed, wherein the energy discharged from the

energy storage device creates a second current that flows through the first sub-circuit opposite the first current, and wherein a substantial portion of the second current flows through the resistor when the second current flows through the first sub-circuit.

5 24. A vehicle as set forth in claim 18 wherein the non-linear device is a first diode, wherein the second sub-circuit further includes a second non-linear device, and wherein the energy storage device and the second non-linear device are electrically connected in parallel branches.

10 25. A vehicle as set forth in claim 24 wherein the first and second non-linear devices each includes a diode, and wherein the energy storage device includes a capacitor.

15 26. A vehicle as set forth in claim 24 wherein the snubber circuit receives a first current flowing from the first port through the first and second sub-circuits to the second port, and wherein a substantial portion of the first current flows through the first non-linear device when the first current flows through the first sub-circuit.

20 27. A vehicle as set forth in claim 26 wherein the energy storage device charges when the first current flows through the second sub-circuit.

25 28. A vehicle as set forth in claim 27 wherein the energy storage device discharges when the contactor is closed, wherein the energy discharged from the energy storage device creates a second current that flows through the first sub-circuit opposite the first current, and wherein the a substantial portion of the second current flows through the resistor when the second current flows through the first sub-circuit.

29. A vehicle comprising:

a motor; and

a control circuit operable to control the motor, the control circuit including a contactor circuit having a contactor, a first end and a second end, and a snubber

circuit connected across the contactor circuit, the snubber circuit including

a first port electrically connected to the first end of the contactor circuit;

a second port electrically connected to the second end of the contactor circuit;

a first sub-circuit electrically connected to one of the first and second ports, the first sub-circuit including a resistor and a first non-linear device electrically connected in parallel branches; and

a second sub-circuit electrically connected in series with the first sub-circuit and to the other of the first and second ports, the second sub-circuit including a energy storage device and a second non-linear device electrically connected in parallel branches.

30. A vehicle as set forth in claim 29 wherein the snubber circuit receives a first current flowing from the first port through the first and second sub-circuits to the second port, wherein a substantial portion of the first current flows through the non-linear device when the first current flows through the first sub-circuit, and wherein the energy storage device charges when the first current flows through the second sub-circuit.

31. A vehicle as set forth in claim 29 wherein the energy storage device discharges when the contactor is closed, wherein the energy discharged from the energy storage device creates a second current that flows through the first sub-circuit opposite the first current, and wherein a substantial portion of the second current flows through the resistor when the second current flows through the first sub-circuit.

32. A vehicle as set forth in claim 30 wherein the first and second non-linear devices each includes a diode, and where the energy storage device includes a capacitor.

33. A method of suppressing arcing in a contactor circuit including a contactor having at least two contacts that make and break an electrical connection, the method comprising the acts of:

providing a snubber circuit including a first sub-circuit and a second sub-circuit electrically connected in series, the first sub-circuit including a first branch having a resistor and a second branch having a non-linear device, and the second sub-circuit including a storage device;

electrically connecting the first sub-circuit to one end of the contactor circuit; electrically connecting the second sub-circuit to the other end of the contactor circuit;

breaking the electrical connection of the contacts; generating a first current in response to the breaking of the electrical connection;

allowing a substantial portion of the first current to flow through the non-linear device; and

charging the energy storage device with energy of the first current.

34. A method as set forth in claim 33 and further comprising the acts of:

after the charging act, making the electrical connection of the contacts; generating a second current in response to the making of the electrical connection, the second current flowing in an opposite direction of the first current; and

allowing a substantial portion of the second current to flow through the resistor.

35. A method as set forth in claim 33 wherein the non-linear device includes a diode.

36. A method as set forth in claim 33 wherein the storage device includes a capacitor.

37. A method as set forth in claim 33 wherein the non-linear device is a first non-linear device, and wherein the second sub-circuit further includes a third branch having a second non-linear device and a fourth branch having the capacitor.

5 38. A method as set forth in claim 37 and further comprising the acts of:
breaking the electrical connection of the contacts a second time;
generating a second current in an opposite direction of the first current in
response to the breaking of the electrical connection the second time;
allowing a substantial portion of the second current to flow through the second
10 non-linear device; and
allowing a substantial portion of the second current to flow through the
resistor.

15 39. A method as set forth in claim 38 wherein the storage device includes a capacitor.

40. A method as set forth in claim 38 wherein the first and second non-linear devices include a first and second diode, respectively.